(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 March 2002 (07.03.2002)

PCT

(10) International Publication Number
WO 02/18521 A2

(51) International Patent Classification[7]: C10M

(21) International Application Number: PCT/EP01/09262

(22) International Filing Date: 10 August 2001 (10.08.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0021041.9 29 August 2000 (29.08.2000) GB

(71) Applicant *(for all designated States except US)*: **EXXON-MOBIL RESEARCH AND ENGINEERING COMPANY** [US/US]; 1545 Route 22 East, Clinton Township, Annandale, NJ 08801 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **PACE, Stuart** [GB/GB]; 19 Varsity Place, John Towle Close, Oxford OX1 4TZ (GB). **HAFEZ, Medi, M.** [CA/US]; 600 Billingsport Road, Paulsboro, NJ 08066-0480 (US). **KOSIDOWSKI, Maria-Laura** [GB/US]; One Franklin Town Apts, 1807, One Franklin Town Boulevard, Philadelphia, PA 19103 (US). **BARBOUR, Robert, Howie** [GB/GB]; The Old Coach House, Hognaston, Ashbourne, Derbyshire DE6 1PW (GB). **SCHILOWITZ, Alan, Mark** [US/US]; 15 N. Sixth Avenue, Highland Park, NJ 08904 (US).

(74) Agents: **DEW, Melvyn, John** et al.; ExxonMobil Chemical Europe Inc., P.O. Box 105, B-1830 Machelen (BE).

(81) Designated States *(national)*: BR, CA, JP, MX, SG, US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/18521 A2

(54) Title: LOW PHOSPHORUS LUBRICATING OIL COMPOSITION

(57) Abstract: This invention relates to a lubricating oil composition used in conjunction with a gasoline fuel having a sulphur content of less than 10 ppm by weight, characterised in that said oil composition has a phosphorus content of no more than 0.05 % by weight. The feature of the invention is that the use of a low sulphur fuel enables the amount of anti-wear agents containing phosphorus such as eg ZDDP to be halved without any adverse effect on the antiwear performance of the lubricating oil.

LOW PHOSPHORUS LUBRICATING OIL COMPOSITION

This invention relates to lubricating oil compositions of low phosphorus content for use in conjunction with ultra-low sulphur gasoline compositions in order to reduce exhaust emissions without adversely affecting fuel economy.

Fuels such as motor gasoline are widely used in automotive transport. However, in line with the general thrust to reduce air pollution, petroleum companies and vehicle manufacturers are looking to develop systems that have reduced exhaust emissions and improved fuel economy. The petroleum companies in turn are introducing fuels with low sulphur content as they are considered to be more compatible with exhaust catalyst systems. Such fuels are generally used in conjunction with lubricating oils which inevitably contain phosphorus in the form of eg zinc dialkyl dithiophosphate (ZDDP). It was believed that low sulphur motor gasoline may transfer less acid species in blow by and therefore impart less stress on the overbased detergency properties of the lubricating oil than would a motor gasoline which is relatively high in sulphur. It was also expected that there would be a corresponding reduction in any adverse impact on the performance of the antioxidant and anti-wear components of such oils. It has also now been recognised that phosphorus also has a detrimental effect on exhaust catalyst systems. Consequently, it has been an objective to develop lubricating oil formulations with reduced phosphorus content. However, whilst ZDDP is the key anti-wear agent in lubricating oil formulations, excessive engine wear can also be reduced to an extent by supplementing ZDDP with other phosphorus-free antiwear agents such as eg oligomeric esters. The issue of wear is of concern, especially with ultra-low sulphur fuels, since the reduction of sulphur content may also adversely affect the lubricity of the resultant fuel and may lead to premature wear in some submerged electric gasoline pumps. Moreover, loss of fuel lubricity may also lead to loss of fuel economy.

Experiments carried out in the context of the present invention have showed that the largest effect of using low sulphur fuels in conjunction with conventional lubricating oils was observed on the anti-wear performance of the lubricating oil formulations as reflected by the iron content of the used oil. It was surprisingly found that low sulphur motor gasoline caused less wear than the high sulphur motor gasoline in spite of the reduced sulphur content which hitherto had been known to adversely affect lubricity. More importantly, this led to the observation that the phosphorus content of the lubricating oil composition could be halved without adversely affecting the wear protection afforded by such oils. Most surprisingly, lowering the phosphorus content of lubricating oils and the sulphur content of the fuel gave a synergistic benefit, providing the lowest iron content of all even though lowering the sulphur and phosphorus content would have been expected to increase wear as indicated by iron content. This suggests that lubricating oils for use in conjunction with low

sulphur fuels can henceforth be formulated with reduced phosphorus levels without adversely affecting wear performance.

Thus, it has now been found that low phosphorus lubricating oils can be used in conjunction with ultra-low sulphur fuels without adversely affecting the fuel economy performance or the efficiency of the exhaust catalyst system of a vehicle.

Accordingly, the present invention is a lubricating oil composition used in conjunction with a gasoline fuel having a sulphur content of less than 10 ppm by weight, characterised in that said oil composition has a phosphorus content of no more than 0.05 % by weight. Thus in one aspect, the invention is the use in an internal combustion engine operating on gasoline fuel having a sulphur content of less than 10 ppm by weight, of a lubricating oil composition having a phosphorous content of no more than 0.05 % by weight, for the purpose of reducing environmental pollution.

As described above, the sulphur content of the fuel composition is less than 10 ppm by weight, is preferably less than 5 ppm by weight. The sulphur measurement methods used were by X-ray (ASTM D2622-1) or by UV (ASTM D5453-93). Such low sulphur levels can be achieved in a number of ways. The base fuels may comprise mixtures of saturated, olefinic and aromatic hydrocarbons and these can be derived from straight run streams, thermally or catalytically cracked hydrocarbon feedstocks, hydrocracked petroleum fractions, catalytically reformed hydrocarbons, or synthetically produced hydrocarbon mixtures such as those derived from methane. Typically, the present invention is applicable to fuels such as the light boiling gasoline (which typically boils between 50 and 200°C), especially motor gasoline. The sulphur content of such fuels can be reduced below the 10 ppm level by well known methods such as eg, catalytic hydrodesulphurisation.

The lubricating oil compositions used in conjunction with the ultra-low sulphur fuels in the present invention are suitably Group II, Group III or Group IV basestock as defined by the API and are preferably Group II basestock. These compositions suitably contain the conventional additives selected from the group consisting of: phenolic and/or aminic antioxidants, demulsifiers, viscosity index improvers, anti-wear agents, alkaline earth metal sulphonates, and polyisobutenyl succinimides which may optionally be borated. These oil compositions suitably have: a kinematic viscosity at 40°C (KV_{40}) of about 75 cSt or less, preferably from 50-75 cSt, more preferably from 60-70 cSt (eg about 66-67 cSt); a KV_{100} of below 20 cSt, preferably from 10-15 cSt (eg about 11 cSt); a pour point below -20°C, preferably below -30°C (eg about -33°C); a flash point of above 200°C, preferably above 215°C (eg 220°C); a NOACK volatility of up to 15% (eg 14.3%); a TBN value of about 7,

eg about 7.15-7.25, eg 7.19-7.22 based on mg of KOH per gram (according to ASTM 2896-98); and a nitrogen content as measured by the Kjeldahl method of below 0.1% by mass, eg 0.08. A typical example of such an oil composition is a 5W40 grade oil.

A feature of the oil compositions of the present invention is that they have a considerably reduced amount of the anti-wear agent, ZDDP, and hence phosphorus therein. For instance, the conventional oil compositions have a phosphorus content of about 0.09-1.0% by weight whereas the lubricating oil composition used in conjunction with the ultra-low sulphur fuels of the present invention need only have a phosphorus content of below 0.05% by weight, eg about 0.046, which is about one-half of that used hitherto with low sulphur fuels. The ZDDP contributing towards the phosphorus content of the lubricating oils used in the present invention suitably have primary alkyl groups having 1-18 carbon atoms, secondary alkyl groups having 3-18 carbon atoms or a mixture of such primary and secondary alkyl groups.

The present invention is further illustrated with reference to the following Examples.

EXAMPLES

The test schedule tabulated below, shows that tests were carried out using low and high sulphur (S) motor gasoline (mogas) and lube oils with low and high phosphorus (P) levels.

	Low P oil (D)	**High P oil (C)**
Low S fuel (B)	3	2
High S fuel (A)		1

The tests were conducted in the order outlined in the table. Tests 1 and 2 were conducted first and after the initial data were analysed the low S fuel in combination with a low P oil was tested. The compositions of the fuels and lubricating oils used are shown in Table 1 below:

Fuels	- High S mogas	A	700ppm S
	- Low S mogas	B	9ppm S

Table 1
Compositional analysis of test fuels

TEST DESCRIPTION	A	B	UNITS
RON	97.6	97.1	
MON	85.0	89.9	
DENSITY	0.766	0.733	g/ml @ 15 °C
APPEARANCE	Fail (partics)	C&B	
EXISTENT GUM	2.2	2	mg/100ml
WASHED GUM	0.8	0	mg/100ml
DISTILLATION			
IBP	25.5	32.2	°C
FBP	199.5	200.7	°C
E70 °C	23.4	36.1	ml
E100 °C	41.8	56.5	ml
E150 °C	87.1	84.8	ml
FIA			
Aromatics	43.8	22	% v/v
Olefins	23.2	0.5	% v/v
Saturates	33	77.5	% v/v
SETAVAP	654	50.9	m/bars / kPa
SULPHUR - XRAY	0.07	*	% wt
SULPHUR - UV	*	9	mg/kg
BROMINE NO.	33.87	0.95	
UVA 319	0.43	0.43	A/Uts
LEAD CONTENT	3.4	<1	mg/l.
NITROGEN		0.3	w/w ppm
Nitrogen in H/Carbons	20.7		w/w ppm
MTBE by IR	0	0	% vol
GC ANALYSIS			
Benzene	N/A	2.23	Vol%
Toluene	N/A	12.56	Vol%
Xylene	N/A	7.21	Vol%
CHN by COMBUSTION			
Carbon	N/A	87.6	%
Hydrogen	N/A	12.4	%
Nitrogen	N/A	<0.1	%

* not measured

Lube oils - High P oil - C) both oils approximate to
Low P oil - D) 5W40 grade

Tables 2-4 below show the formulation details and compositional analysis of these lube oils.

Table 2
High P Lube oil formulation (C)

Component	Component chemistry	blend ratio
PBR 9330	300 TBN Ca Sulphonate	1.55
PBR 9260	Borated PIBSA PAM MWt 2225	6
PX 14	ZDDP with *sec*-alkyl groups	1.2
IRG L150	mixed phenolic/aminic Antioxidants	1
PBR 9499	Demulsifier	0.01
PTN 8464	Viscosity Improver	8.8
IOL 120X b'stock	GPII basestock	81.44

Table 3
Low P lube oil formulation (D)

Component	Component chemistry	blend ratio
PBR 9330	300 TBN Ca Sulphonate	1.55
PBR 9260	Borated PIBSA PAM MWt 2225	6
PX 14	ZDDP with *sec*-alkyl groups	0.6
IRG L150	mixed phenolic/aminic Antioxidants	1
PBR 9499	Demulsifier	0.01
PTN 8464	Viscosity Improver	8.8
IOL 120X b'stock	GPII basestock	82.04

Table 4
Fresh oil analysis

Test	Units	C High P Research oil	D Low P Research oil
KV40	CSt	67.3	66.32
KV100	CSt	11.3	11.08
Ravensfield viscosity	MPa.s	3.2	
EPCo CCS -25C auto	MPa.s	2810	
Pour point (auto)	°C	-33	
EPCo LPTV -35°C	CP	21700	
COC Flash point (auto)	°C	220	
NOACK volatility	%	14.3	
TBN	Mg KOH/g	7.19	7.22
Additive Elements			
Boron	% wt	0.015	0.014
Barium	%wt	<0.001	<0.001
Calcium	%wt	0.179	0.179
Copper	%wt	<0.001	<0.001
Magnesium	%wt	<0.001	<0.001
Molybdenum	%wt	<0.001	<0.001
Phosphorus	%wt	0.093	0.046
Sulphur	%wt	0.226	0.13
Silicon	mg/kg	4	5
Zinc	%wt	0.105	0.052
N content (Kjeldhal)	%m/m	0.082	
Foam stage 2			
Foam after 5min blowing	ml	0	
Foam after 10min settling	ml	0	

Engine testing

All engine testing was carried out on a GM Buick 3.8L engine. The standard cycle for this engine is medium severity and has a duration of 109 hrs and the protocol used is summarised in Table 5 below using an Exxon in-house procedure:

Table 5
Engine test cycle

GM Buick 3.8L engine			
Stage	**Duration** min:sec	**Engine speed** Rev/min	**Torque** Nm
1	10:50	1700	48.8
2	15:57	1465	76.2
3	10:50	1700	48.8
4	24:08	1465	76.2
5	17:35	1265	36.6
6	15:57	1465	76.2

Under standard testing conditions used, the sump is flushed and filled with the oil under test ("Test oil") before the test commences. At the end of test the cylinder head is removed and the level of intake valve and combustion chamber deposits measured (visual rating and/or weights).

To test the compositions of the present invention the engine was flushed with the low P oil prior to filling and then the test was run under the standard cycle. At the end of test the engine was dismantled and rated in the normal manner and the used oil was collected for analysis. Small (ca. 50ml) oil samples were collected during the test, after 24, 48 and 72 hours, so that effects could be monitored throughout the test.

Used oil analysis - Bench test strategy

Samples of the fresh and end of test (EOT) used oils were analysed for all of the tests and these are listed below (Tables 6 and 7). In addition, the intermediate samples, which were only available in limited quantities (50ml), were analysed by a limited test set (Table 6).

Table 6
Tests for all oil samples

	Purpose	Test	Volume
1	Free acid	TAN	25
2	Detergency retention	TBN	25
3	Anti-oxidancy	DSC stepped temp	20
4		DSC isothermal	20
5	Wear	Wear metals	5

Table 7
Additional tests for fresh and EOT oils

	Purpose	Test	Volume
6	Viscometric change	KV_{40}	50
7	Viscometric change	KV_{100}	50
8	Fuel dilution	Fuel dilution	30
9	Wear	Additive metals	5

Results obtained are summarised in Table 8-11 below. In these Tables the concentration of metals which did not undergo any significant change as a result of the test are not reported. In the Tables, the Wear metals by ICP tests were carried out as prescribed in ASTM D5185 and the KV values determined according to ASTM D445.

Table 8A
Engine Test IVD Results

Measurement	High S Fuel (A)	Low S Fuel (B)
IVD rating	6.3	7.5
IVD mg/valve (average)	1368	378

Table 8B
Engine test CCD Results

Measurement	High S Fuel (A)	Low S Fuel (B)
CCD mg/cylinder (average)	1256	551
PTD mg/cylinder (average)	1505	698
Total	*2761*	*1249*

Table 9
Bench test results for virgin and EOT used oils (Engine Tests 1 and 2)

	Lube Oil Sample description	**C Virgin oil**	**EOT Low S Fuel**	**EOT High S Fuel**
Test	Units			
Kinematic Viscosity at 40°C (ASTM D445)	cSt	68.1	64.8	65.8
Kinematic Viscosity at 100°C (ASTM D445)	cSt	11.3	11.0	11.0
TAN (ASTM D664)	mg KOH/g	1.95	1.78	2.05
SAN (IP 182/82)	mg KOH/g	0	0	0
pH		7.86	5.64	5.62
TBN (ASTM D2896)	mg KOH/g	7.17	6.63	6.24
% loss		0	8	13
Fuel dilution (IP 23/83)	% v/v	No dilution	No dilution	0.20
DSC Oxidation stability 5°C/min				
Degradation Temperature	°C	247.8	227.0	225.8
Extrapolated Onset Temperature	°C	250.2	233.6	230.3
Reduction in Degradation Temp	°C	0	16.6	19.9
DSC Oxidn Stability 210°C/200ml				
Induction time	Min	53.3	19.3	12.6
Extrapolated onset time (EOT)	Min	55.2	20.5	13.8
Reduction in Induction time	Min	0	34	40.7
Wear metals by ICP (ASTM D5185)				
Barium	mg/kg	<1	2	2
Chromium	mg/kg	<1	<1	2
Copper	mg/kg	<1	4	14
Iron	mg/kg	<1	17	40
Molybdenum	mg/kg	2	3	3
Phosphorus	mg/kg	>180	>180	>180
Lead	mg/kg	<1	<1	3
Silicon	mg/kg	2	66	63
Det. Used Oil Elements (ASTM D5185)				
Boron	% wt	0.014	0.008	0.008
Magnesium	%wt	<0.001	<0.001	0.005
Phosphorus	%wt	0.093	0.087	0.082
Sulphur	%wt	0.224	0.204	0.253
Silicon	mg/kg	3	>50	>50

Table 10

Results for fresh oil, EOT oils and intermediate samples (Engine Tests 1 and 2)

Test		Low S fuel B					High S fuel A				
	Time (hrs)	0	24	48	72	EOT	0	24	48	72	EOT
TAN	mg KOH/g	1.51	1.69	1.75	1.79	2.1	1.51	1.73	1.76	1.97	2.2
SAN	mg KOH/g	0	0	0	0	0	0	0	0	0	0
pH		8.47	7.32	6.55	6.28	5.95	8.47	7.46	6.65	5.96	6.11
TBN	mg KOH/g	7.16	6.92	6.86	6.87	6.62	7.16	7.06	7.01	6.89	6.24
% loss		0	3	4	4	8	0	1	2	4	13
DSC Oxidn stability 5°C/min											
Degradation Temperature	°C	251.2	243.0	239.6	234.1	231.9	251.2	238.1	234.9	230.1	226.4
Extrapolated Onset Temp	°C	252.6	244.7	242.3	237.7	234.6	252.6	241.1	237.8	235.4	231.6
Reduction in Degn Temp	°C	0.0	7.9	10.3	14.9	18.0	0.0	11.5	14.8	17.2	21.0
Reduction in Degn Temp	%	0.0	3.1	4.1	5.9	7.2	0.0	4.6	5.9	6.8	8.4
DSC Oxidn Stability 210°C/200ml											
Induction time	Min	57.4	43.6	36.7	30.3	23.5	57.4	23.6	21.1	20	15.2
Extrapolated onset time (EOT)	Min	60	44.8	37.8	31.5	24.5	60	24.6	22.6	21.3	16.4
Reduction in Induction time	Min	0	13.8	20.7	27.1	33.9	0	33.8	36.3	37.4	42.2
Reduction in Induction time	%	0	23	35	45	57	0	56	61	62	70
Wear metals by ICP											
Copper	mg/kg	<1	3	2	3	4	<1	11	11	12	14
Iron	mg/kg	<1	8	10	14	17	<1	11	19	25	40
Sodium	mg/kg	<1	5	5	5	5	<1	7	7	7	6
Phosphorus	mg/kg	>180	>180	>180	>180	>180	>180	>180	>180	>180	>180
Lead	mg/kg	<1	<1	<1	<1	<1	<1	4	2	2	2
Silicon	mg/kg	2	38	50	59	69	2	36	50	57	67

Table 11

Results for fresh oil, EOT oils and intermediate samples (Engine Test 3)

		Low S fuel B				
		Fresh oil	24hrs	48hrs	72hrs	EOT
Test	Units					
TAN	mg KOH/g	1.32	1.12	1.15	1.27	1.6
SAN	mg KOH/g	0	0	0	0	0
pH		9.29	7.09	6.59	6.18	6.99
TBN	mg KOH/g	7.22	6.84	6.71	6.44	5.76
% loss		0	6	7	11	22
DSC Oxidation stability 5°C/min						
Degradation Temperature	°C	244.8	235.6	230.1	224.4	217.6
Extrapolated Onset Temperature	°C	246.8	237.3	232.1	226.9	220.2
Reduction in Degradation Temp	°C	0	9.2	14.7	20.4	27.2
Reduction in Degradation Temp	%	0	4	6	8	11
DSC Oxidn Stability 210°C/200ml						
Induction time	Min	33.7	18.6	13.3	5.8	1.2
Extrapolated onset time (EOT)	Min	35.1	19.7	14.3	6.6	1.9
Reduction in Induction time	Min	0	15.1	20.4	27.9	32.5
Reduction in Induction time	%	0	45	61	83	96
Wear metals by ICP						
Copper	Mg/kg	<1	7	7	8	9
Iron	Mg/kg	<1	5	6	6	6
Sodium	Mg/kg	<1	5	5	5	6
Phosphorus	Mg/kg	>180	>180	>180	>180	>180
Silicon	Mg/kg	3	36	45	53	63
Det. Used oil Elements						
Copper	%wt	<0.001				<0.001
Phosphorus	%wt	0.046				0.044
Sulphur	%wt	0.13				0.126
Silicon	Mg/kg	5				52
KV_{40}	CSt	66.32				65.62
KV_{100}	CSt	11.08				10.95
Fuel dilution						None

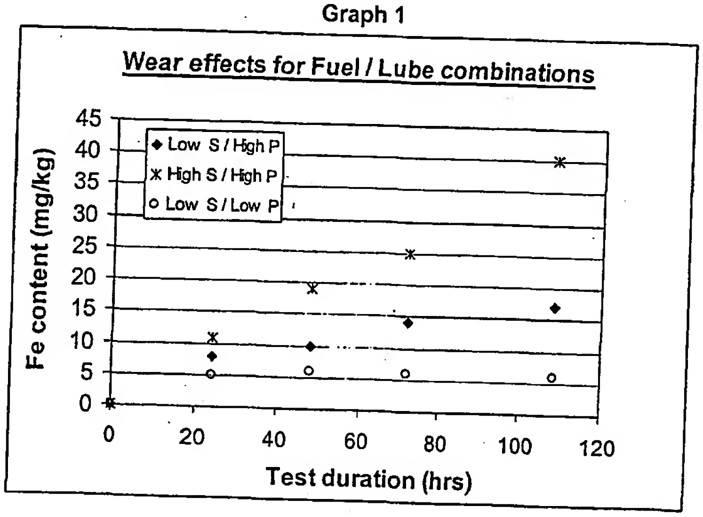
Due to a complex interplay between the different fuel properties the interpretation of these data is not straightforward. For example, oil viscosity can be impacted in a number of ways, e.g. fuel dilution can reduce viscosity while oxidation and particulate suspension can increase it. Likewise, the S content of the oil can be increased through the transfer of combustion products via blow-by but could be reduced through the reaction of ZDDP or through fuel dilution. However, there are some interesting effects observed from these data.

The main observations made are summarised below.

Wear effects

* When the high P oil was used the Fe content was higher in the used oil run on the high S mogas.
  - Results for the intermediate samples were consistent with this (see Graph 1 below).
  - Lower levels of P and Zn were measured in the same oil samples. The differences are small but are consistent and based on original oil analyses are reproducible.

Graph 1



* When the low P oil was tested in combination with low S mogas the level of Fe was even lower than in tests 1 and 2.
  - This was somewhat surprising as the lower concentration of ZDDP should have led us to expect higher levels of Fe (vs test 2)
  - Other results (e.g. DSC) are consistent with lower levels of ZDDP in the oil.

* The stepwise reduction in Fe levels from test 1 to test 2 to test 3 may give the impression of a gradual decrease in severity over time. However, current knowledge of engine testing would not support this. Furthermore, the test engine was not new at the start of this study and thus had been fully run-in in earlier test work.

Anti-oxidancy

* Lube oils run on low S mogas retain more anti-oxidancy performance at the end of test.
  - The used oils from test 1 (high S mogas) had a slightly lower DSC degradation temperature and a slightly shorter induction time than the corresponding oils from test 2.

* The anti-oxidancy performance of the oil deteriorated when the ZDDP concentration was halved. This was to be expected since ZDDP is also known to have antioxidancy properties in addition to being an anti-wear agent. Thus, it may be necessary to supplement the amount of anti-oxidants used in the formulations for optimum performance.

Acid Neutralisation

* The fuel composition may also impact the rate of TBN loss and increase in TAN but only to a small extent
  - The oil run on low S mogas (test 2) lost less TBN than that from test 1.
  - The oil run on high S mogas (test 1) has a higher TAN than that from test 2.
  - The oil from test 3 (low P oil / low S mogas) showed the largest reduction in TBN

S content

* The S content of the used oil also appears to be influenced by the fuel composition
  - The oil run on high S mogas (test 1) shows a greater S increase than the fresh oil while the oil run on lower S mogas (test 2) has a slightly lesser S increase.
  - When the low S mogas was run with the low P oil the EOT oil had about the same S content as the fresh oil.

Viscosity

* All of the EOT oils have slightly lower viscosity than the virgin oil.

Fuel dilution

* Little or no fuel dilution was observed in any of the tests.

CCD/IVD

* The high S base fuel created a significantly higher level of deposits (CCD and IVD) than the low S mogas.

The testing now carried out shows that:

Fuel composition does appear to impact lube oil performance in key areas. The largest effect observed was in anti-wear performance as reflected in the Fe content of the used oil. The low S mogas caused less wear than the high S mogas. Using the low S mogas, the P content of the oil could be halved with no detrimental effect in wear protection.

Low S mogas also appears to have less of a detrimental effect on the anti-oxidancy and acid neutralisation (TBN) performance of the oil.

Claims:

1. A lubricating oil composition used in conjunction with a gasoline fuel having a sulphur content of less than 10 ppm by weight, characterised in that said oil composition has a phosphorus content of no more than 0.05 % by weight.

2. A lubricating oil composition according to Claim 1 wherein said composition is used in conjunction with a gasoline having less than 5 ppm by weight of sulphur.

3. A lubricating oil composition according to Claim 1 or 2 wherein said composition comprises Group II, Group III or Group IV basestock as defined by the API.

4. A lubricating oil composition according to any one of the preceding Claims wherein said composition has: a kinematic viscosity at 40°C (KV_{40}) of about 75 cSt ir less and at 100°C (KV_{100}) of below 20 cSt; a pour point below -20°C; a flash point of above 200°C; a NOACK volatility of up to 15%; a TBN value of about 7 based on mg of KOH per gram (ASTM 2896-98); and a nitrogen content as measured by the Kjeldahl method of below 0.1% by mass.

5. A lubricating oil composition according to any one of the preceding Claims wherein said oil is a 5W40 grade oil.

6. A lubricating oil composition according to any one of the preceding Claims wherein said composition comprises in addition one or more additives selected from the group consisting of: antioxidants, viscosity index improvers, anti-wear agents, demulsifiers, alkaline earth metal sulphonates and polyisobutenyl succinimides which are optionally borated.

7. A lubricating oil composition according to any one of the preceding Claims wherein said composition comprises zinc dialkyldithiophosphate (ZDDP) as an anti-wear agent in an amount such that the phosphorus content of the composition is below 0.05% by weight.

8. A lubricating oil composition according to Claim 7 wherein the ZDDP has primary alkyl groups having 1-18 carbon atoms, secondary alkyl groups having 3-18 carbon atoms or a mixture of such primary and secondary alkyl groups.

9. A lubricating oil composition according to any one of the preceding Claims 6-8 wherein the antioxidant is phenolic, aminic or mixtures thereof.

10. A method of operating internal combustion engines which method comprises using a lubricating oil composition in conjunction with a gasoline fuel having a sulphur content of less than 10 ppm by weight, characterised in that said lubricating oil composition has a phosphorus content of no more than 0.05 % by weight.

11. A method for reducing wear in an internal combustion engine said method comprising using a lubricating oil composition in conjunction with a gasoline fuel having a sulphur content of less than 10 ppm by weight, characterised in that said lubricating oil composition has a phosphorus content of no more than 0.05 % by weight.

12. A method of reducing environmental pollution caused by the operation of an internal combustion engine whilst also reducing wear in said engine, said method comprising using a lubricating oil composition in conjunction with a gasoline fuel having a sulphur content of less than 10 ppm by weight, characterised in that said lubricating oil composition has a phosphorus content of no more than 0.05 % by weight.

13. The use in an internal combustion engine operating on gasoline fuel having a sulphur content of less than 10 ppm by weight, of a lubricating oil composition having a phosphorous content of no more than 0.05 % by weight, for the purpose of reducing environmental pollution.

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☑ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: ______________________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.